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ABSTRACT

The Zimbabwe Secondary School Science Project (ZIM-SCI) developed student study guides, corresponding teaching guides, and science kits for a low-cost science course which could be taught during the first 2 years of secondary school without the aid of qualified teachers and conventional laboratories. This ZIM-SCI study guide presents activities and experiments for a unit dealing with: (1) the generation of electricity; (2) uses of electricity in everyday life; and (3) safety precautions when using electricity in the home and in commerce and industry. Major areas investigated include: work and electrical power; changing electrical energy into other forms of energy; magnetic fields due to adjacement permanent magnets; the motor effect of an electric current; electromagnetic induction and generators; precautions related to using household electricity; and paying for electrical power. Information is provided throughout the unit to help students understand the concepts behind the activities and experiments. (JN)

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ZIMBABWE SECONDARY SCHOOL SCIENCE PROJECT

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STUDY GUIDE UNIT 12

USING ELECTRICITY

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UNIVERSITY OF ZIMBABWE
AND MINISTRY OF EDUCATION AND CULTURE

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September 1983

ZIM-SCI

ZIMBABWE SECONDARY SCHOOL SCIENCE PROJECT

GENERAL SCIENCE

STUDENTS: Please read this carefully. It will help you.

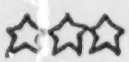
How you will study

This Study Guide comes to you with a kit of apparatus. Both things are part of a study programme leading you to an understanding of aspects of science. In this course you will be carrying out experiments. The Study Guide will help you to understand the scientific principles behind the experiments.

Your work should be done as you are instructed, either by the teacher or the Study Guide.

To help you to see quickly what you must do, the Study Guide uses these symbols:

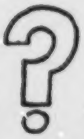
for "Read and revise your notes and Study Guide"



for "Take note of an important point that you should learn"

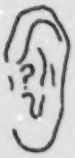
for "Summary. This is to help you to go over what you have learned"

for "Experiment"
When you see this sign, read the instructions carefully from beginning to end before you start to do the experiment.



for "How much do you know?"
This is for you, to help you to test whether you are remembering what is important.

for "Written work"
This is when you must answer questions in writing.



for "Listen to the teacher and do exactly what the teacher tells you to do"

for "Activity"
This symbol will appear whenever you are asked to do something without your apparatus.

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AIMS OF THIS UNIT

At the end of this Unit you will be able to:-

1. Describe what electric power is and calculate the power of an electric light bulb.

2. Carry out simple experiments to observe the heating effect and the magnetic effect of electricity.

3. Find the effect of one permanent magnet on another and demonstrate the magnetic lines of force.

4. Investigate the effect of a magnet on a moveable conductor through which electricity flows.

5. Make a model of an electric motor, explain how it works and compare it with a factory-made motor.

6. Generate (produce) a direct current (D.C.) and an alternating current (A.C.) from a dynamo or generator.

7. Explain the difference between D.C. and A.C.

8. List the dangers associated with the electrification of our National Railways.

9. Explain how electricity from a generator gets to houses.

10. Explain the difference between the lighting and the ring-main (power) circuits.

11. Wire a power plug correctly.

12. Choose a suitable fuse for a particular appliance.

13. Explain how earthing of electrical power appliances protects against electrical shocks.

14. Define a unit of electrical energy.

15. Read an electric meter to work out the units consumed and calculate the cost to the consumer.

UNIT 12

PART 1

WORK AND POWER

So far in our study of electricity you have learnt about circuits, how electricity is transferred from place to place, and how it behaves when electrical energy is changed into other forms.

A common word used when talking about electricity is electrical POWER. We will begin this second unit on electricity by thinking about WORK and POWER.

WHAT IS WORK?

You may think you have done a great deal of work if you spend an hour solving problems on circuits. However, according to the meaning we give in science to the term "work", this is not so. In science WORK is the AMOUNT OF ENERGY TRANSFERRED OR CHANGED. Since you did not transfer any energy in solving problems it follows that you did NOT do any work.

In the unit on FORCES you learnt that:

1. Weight is a FORCE which is measured in newtons (N).

2. Work done depends upon the force (measured in N) and the distance (measured in metres) moved in the direction of force.

   Therefore: Work = Force (N) x Distance (m) moved in the direction of FORCE = Nm.

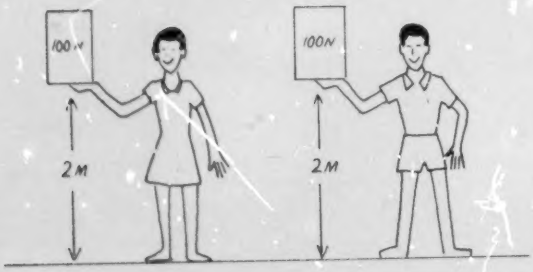
3. A JOULE is a unit of energy and is equal to 1 Nm.

   1 J = 1 Nm

   Therefore Work = Nm = J

   (Note that a JOULE is a unit of work as well as energy.)

HOW MUCH WORK HAVE YOU DONE IN RAISING 100N?



Working

Work = Force x Distance

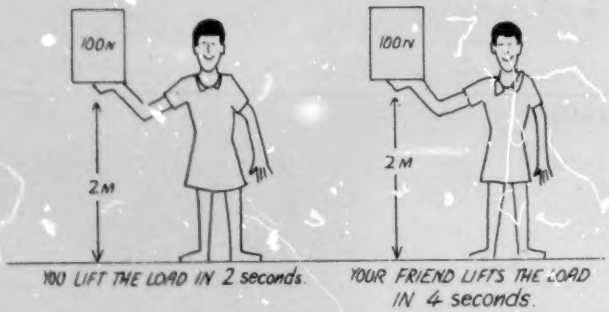
= 100 x 2 Nm

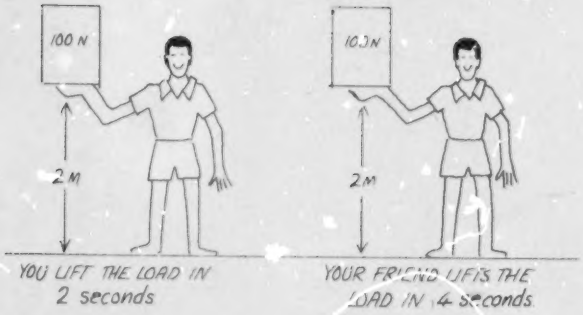
= 200 Nm

= 200 J (1 Nm = 1 J)

The work you have done is 200 J. You have transferred chemical energy from your muscles to uphill (potential) energy of the load.

HOW FAST CAN WORK BE DONE?





After 2 and 4 seconds both of you will have done the same work.
Who works faster? Good! You of course!
Let us work out how much energy is transferred in one second.

Work done by you in 1 second = $\frac{100 \times 2}{2}$ J

$= 100$ J

Work done by a friend in 1 second = $\frac{100 \times 2}{4}$ J

$= 50$ J

Which of you is more powerful?
The one with more power does MORE WORK in the same time than the one with LESS POWER.

Because you did more work in 1 second than your friend in the same time, we conclude that you have MORE POWER.

☆☆☆

From the example above we can now say that POWER IS ENERGY TRANSFER PER SECOND OR WORK DONE PER SECOND. In other words Power is a RATE of energy transfer or work being done.

It can be calculated by:

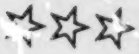
$$\text{Power} = \frac{\text{Energy transferred}}{\text{Time taken}}$$

$$= \frac{\text{Work done}}{\text{Time taken}}$$

Thus your Power is 100 J/s and your friend's Power is 50 J/s.
This means that you transfer energy faster than your friend.

UNIT OF POWER

A Joule per second (J/s) is a unit of power. This unit (J/s) is called a WATT (W).



1 WATT(W) = 1 J/s

What is your power in Watts? Good!
It is 100 W. Your friend's power is 50 W.

What you have just done appears to have nothing to do with electricity. Let us find out if this is so.

ENERGY AND ELECTRICITY

When a current flows through an energy converter for example a torch bulb, it delivers energy to it. This means that the electricity is doing work in the bulb converting electrical energy into heat and light.

The energy is carried by the current. Current is of course a rate of flow of electricity *so the rate of delivery of energy must be the available energy multiplied by the rate of flow*, in other words the voltage x current. Think about this very carefully for a few minutes. It is a very important part of electrical science!

What is the rate of energy delivery?

Good, it is POWER as we have just revised on the previous page.

We can write this as another mathematical equation:

Power = Volts X Amperes

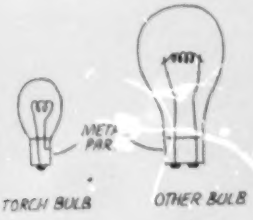
or

Watts = Volts X Amperes

POWER OF LIGHT BULBS

If one day you went to town and walked into an electrical shop you would see bulbs of different shapes and sizes. In order to buy the correct bulb, you must know its power. A 40W bulb is used in the table lamp for reading, a 60W bulb is used to light a small room and a 100W bulb for lighting a big room. So if you do not know the power of the bulb you will end up buying the wrong one.

Every electrical appliance has two numbers marked on it. With electric bulbs these may be marked on the metal part or on the glass bulb. Take a torch bulb and a bulb from the light kit.



Look for numbers marked on the metal part of each.
The torch bulb I used had the following numbers: 2,5V 0,3A and the other bulb had these numbers: 6V 5W.

The power of the torch bulb can be found by using the power equation:

WATTS = VOLTS x AMPERES

= 2,5 x 0,3

= 0,75.

The power of the lamp is 0,75 Watts.

The other bulb has power and potential difference (p.d.)
To find the correct current we use the same power equation.

Watts = Volts x Amperes

5 = 6 x Amperes

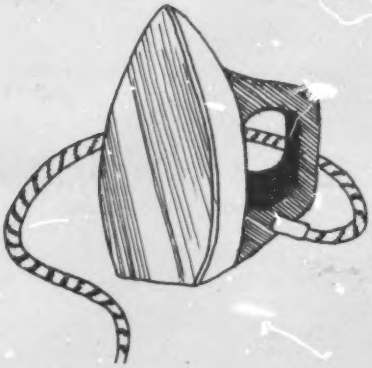
Therefore Amperes = $\frac{5}{6}$

= 0,8.

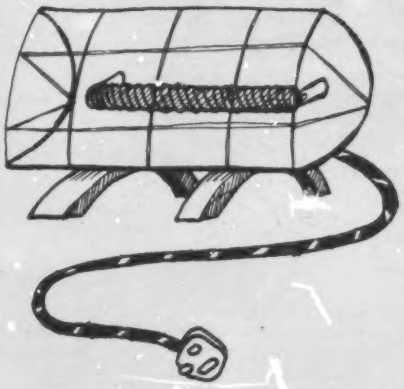
The current required is 0,8A.
The usual numbers marked on the appliance are watts and p.d. like in the last bulb.

Usually electric bulbs have the following numbers marked on them: 40W 230V, 100W 230V, 150W 230V.

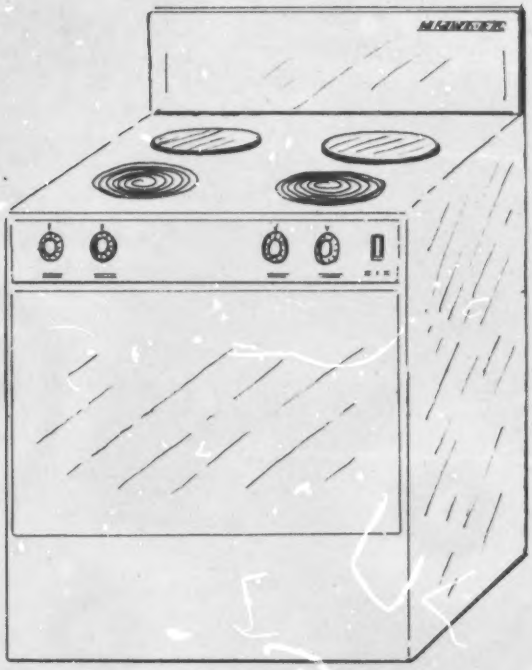
POWER APPLIANCES



ELECTRIC IRON



ELECTRIC HEATER

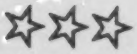


ELECTRIC STOVE

Electric irons, heaters or cookers are examples of appliances used in modern homes to provide heat etc. These need a lot of power which is usually marked somewhere on the appliance. An electric heater may have the following numbers 1000W 230V and a cooker 1100W 230V marked on it. These powers are much larger than those of the torch bulbs.

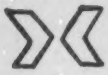
Note that a 100W bulb converts 100 J/s of electrical energy into heat and light and a 1000 W heater converts 1000 J/s of electrical energy into heat.

Go over your work on power and then do Exercise 1 .



SUMMARY

1. Work is the amount of energy transferred or changed.



2. A JOULE (J) is a unit of work as well as energy.

3. (a) Electrical power is energy transferred per second OR work done per second.

   (b) POWER = AMPERES X VOLTS.

   (c) A WATT (W) is power delivered or transferred when one joule of work is done in one second.

   1W = 1 J/s = Ampere x Volt.

CHANGING ELECTRICAL ENERGY INTO OTHER FORMS

1. LIGHTING EFFECT OF ELECTRICAL ENERGY

In Unit II we dealt mainly with bulbs. These bulbs glowed dimly or brightly depending upon the current and useful energy (p.d.) supplied in the circuit. Hence electric bulbs are energy converters. They convert electrical energy into heat and light. In bulbs the emphasis on light energy. The filaments become white hot so as to produce light.

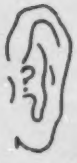
2. HEATING EFFECT OF ELECTRICAL ENERGY

An electric cooker or heater is made in such a way as to produce heat and less light. These and many others convert electrical energy into heat.

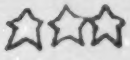
How do they do this.

You remember towards the end of Unit II we discovered that if potential difference exists across a resistance a current flows in it which is dependent on the size of the resistance. If the resistance is very large the current is very small and if the resistance is small the current is large. We also noticed that the resistance became high as the available energy was converted into heat by the current being forced through it.

A resistor can become hot or even glow if the current is high enough.



This is exactly what we are going to do in the following demonstration which you and your teacher are going to do. Leave your desks for the teacher's table for the demonstration. Observe carefully what goes on and then answer the questions your teacher will ask you.



A resistor which only becomes red-hot without becoming white-hot is used to convert electrical energy into heat. Such resistors are called ELEMENTS. Do not confuse the heat element with the chemical element.

Below are a few examples of electrical appliances which produce heat.

Electrical kettle, heater and stove are but a few examples of appliances which produce heat energy.

3. MAGNETIC EFFECT OF ELECTRICAL ENERGY

In Unit A1 you discovered that some metals are attracted by a magnet. Do you still remember which these metals were? Later in Unit C1 you separated a mixture of iron filings and sulphur by means of a magnet. Which of the constituents of the mixture was attracted by the magnet?

☆☆☆

Iron and iron filings are attracted by a magnet. A magnet possesses MAGNETISM which attracts magnetic substances such as iron and steel.

How does electricity come into the picture of magnets and magnetism?
Is there a connection between electricity and magnetism?
These questions can be answered by carrying out the following experiment.

EXPERIMENT 1 : TO FIND OUT IF ELECTRICITY PRODUCES MAGNETISM

You will need:

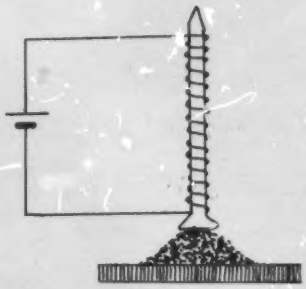
a new cell
leads (3)
a 5 cm iron nail
iron filings in evaporating dish.

Collect some iron filings from your teacher in an evaporating dish.

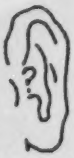
Heap the iron filings on your desk.

Touch the iron filings with the head of the nail. Lift the nail. Are filings attracted? If so, how many? (lots or only a few)

Wind one lead around the whole nail. Touch the filings with head of the coiled nail. Are iron filings attracted? If any are attracted remove them

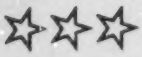


Connect the coiled nail to the cell using the other two leads. Quickly touch the filings with the nail head. Raise the nail gently. Does the nail attract iron filings this time? Break the circuit. What happens to the filings? Complete the circuit and repeat. What happens again? Break the circuit.



Does the nail become a magnet simply by winding a lead around it?
When is the nail a magnet?
Does the nail keep its magnetism when the circuit is broken?

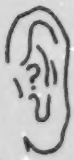
Discuss this with your teacher.



Magnetism is always produced whenever electricity passes through a conductor e.g. a coil. This magnetism is called ELECTROMAGNETISM. The coil (with iron, inside it) is called an ELECTROMAGNET.

The presence of the iron nail makes the electromagnet powerful or strong. The electromagnet loses its magnetism once the electricity is cut off.

We can, therefore, say electricity has "readiness-to-make-magnets" property. This property is called the magnetic effect. Magnetism is always produced whenever electricity passes through a conductor: coiled or straight.



NOTE: It is this electromagnetism which affects the reception of your radio when a motorcar passes nearby.

Your teacher will tell you how.

Electrical energy has several effects i.e. It can be converted into other forms of energy. These effects are:

1. LIGHTING EFFECT

The filament in electric bulbs becomes white hot and so produces light.

2. HEATING EFFECT

The heating element becomes red-hot and so produces heat.

3. MAGNETIC EFFECT

Magnetism (electromagnetism) is produced when electricity passes through a conductor.

Note that electricity also has a chemical effect which you used in Unit F2 to purify copper. You will learn more about this effect in the O-Level course.

PERMANENT MAGNETS

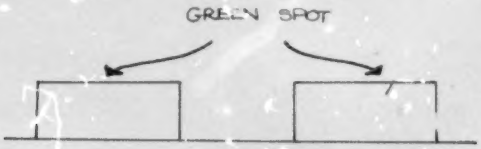
The small magnets you used in Unit A1 keep their magnetism. Such types of magnets are called permanent magnets as opposed to electromagnets which are magnets (possess magnetism) only when electricity passes through the conductors. You might have noticed, too, that one side of the magnet has a painted spot (green or red). Let us play with these magnets and find out the effect of one magnet on the other in the following experiment.

EXPERIMENT 2 : EFFECT OF ONE MAGNET ON ANOTHER.

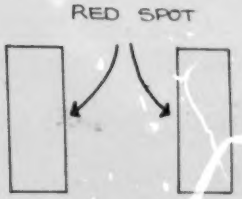
You will need:

two small magnets (from electric motor kit).

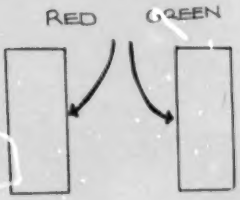
Hold a magnet in each hand with the green sides facing each other. Move the magnets closer to each other until they are about one centimetre or less apart.
What do you feel?
Move them closer still. What do you feel now?

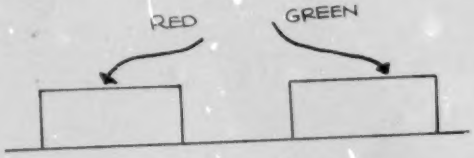


Then place both magnets in line on your desk with the green sides on top.
Push one magnet towards the other. What do you see?
Does the magnet you are pushing pull or push the other magnet?



Repeat the experiment using the red sides.
What do you see and feel?
Is the other magnet pulled (attracted) or pushed (repelled) by the one you are pushing?





Lastly, repeat the experiment this time using the red and green sides.
What happens? Do they attract or repel each other?

Now do Exercise 2.

Same (like) sides (poles) of magnets repel each other and opposite (unlike) poles attract each other.

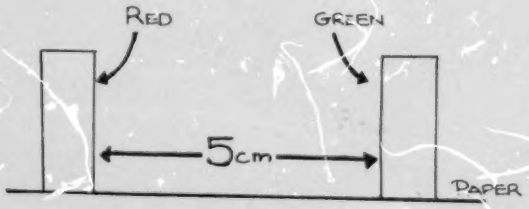
The green side is the North Pole (N) and the red side is the South Pole (S) of a magnet. Thus a magnet has two poles, a N and a S.

The results of the experiment above made us aware of the existence of forces produced by magnets. You saw magnets attracting and repelling. Let us investigate further these forces which are produced by magnets.

EXPERIMENT 3 : A WAY OF MAKING FORCES VISIBLE

You will need:

2 magnets
a sheet of paper
a ruler
iron filings in evaporating dish.



Place a sheet of paper on your desk. Place your magnets 5 cm apart with the red and green sides facing each other. Pinch up some iron filings and sprinkle them lightly between the magnets. Tap the paper gently. Do you see a pattern of lines formed by the iron filings?
You may sprinkle some more iron filings if the pattern is not clear.
Repeat the experiment using two like poles (green-green or red-red)

Do you see a pattern?
Is the pattern the same as the one you have just seen?

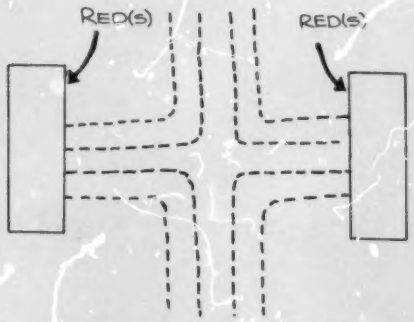
MAGNETIC FIELD

The magnetic force surrounding the magnet is shown by where the iron filings are. The stronger the force the more iron filings collect there. Scientists call the space around a magnet where the force can be detected a MAGNETIC FIELD.

Although the field is continuous throughout the space around the magnet, the iron filings seem to put themselves in lines. These lines are a useful way of describing the shape of a magnetic field and are called LINES OF FORCE.

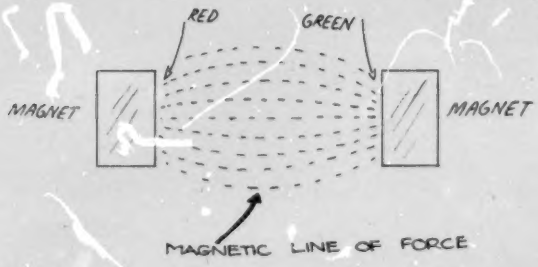
Lets have a look at different kinds of magnetic fields.

MAGNETIC FIELD DUE TO TWO LIKE POLES NEAR EACH OTHER.



The magnetic field consists of lines of force which repel each other. These repelling lines of force keep the magnets apart.

MAGNETIC FIELD DUE TO TWO UNLIKE POLES NEAR EACH OTHER.



Here the lines of force between the magnets join the two poles resulting in attraction.

☆☆☆

A magnet has two poles - a N and a S at either end. Around the magnet there is a magnetic field. When two like poles of magnets are near each other they repel i.e. the fields repel each other. When two unlike poles are near each other they attract.

Now do Exercise 3

EFFECT OF THE MAGNETIC FIELD OF A PERMANENT MAGNET ON A CONDUCTOR OF ELECTRICITY.

A magnetic field exists around a conductor when electricity flows through it. Remember! Also a magnetic field exists around a permanent magnet. What will happen when a moveable conductor through which electricity passes is placed near a permanent magnet? Will there be any movement? Discuss this with your partner. Then carry out the following experiment to find out.

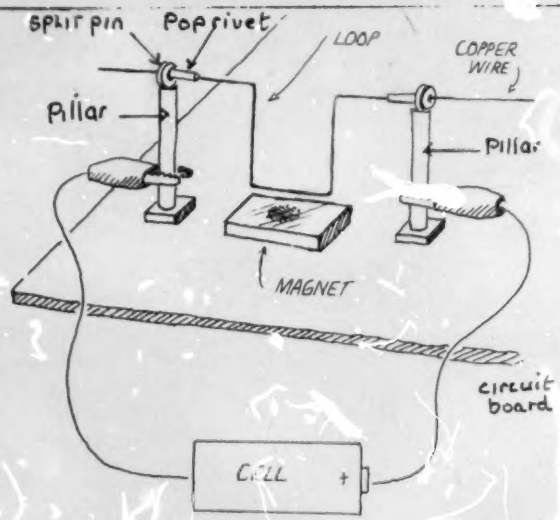
EXPERIMENT 4 : WHAT HAPPENS TO A MOVEABLE CONDUCTOR WHEN A A MAGNET IS PLACED NEAR IT?

You will need:

a small magnet
black and red leads
circuit board
15cm spare copper wire from electric motor kit
emery paper
matches
burner
split pins (2) /split pins with rivets
pop rivets (2)
a cell or two

Measure 15cm of spare copper wire. Cut it off and remove the insulation by heating the wire with a burner. Clean the wire thoroughly with emery paper or other rough surface. Then bend the copper wire so that it has a loop and two straight ends as in the diagram above. Adjust the size of the loop so that the bend will just pass over the magnet when it is assembled as shown in the following diagram.

Do NOT complete the circuit yet.



Check to see if the loop moves fairly easily.

Connect one end of the lead to one end of the cell. Touch briefly the other end of the cell and note what happens to the loop. If nothing happens then turn the split pins sideways slightly so that there is a better contact between the copper wire and the rivet. Complete the circuit briefly. What happens to the loop? Note which way the loop moves. Complete the circuit to check the movement of the loop.

Next use the other side (pole) of your magnet. Complete the circuit and note the direction of movement of the loop. From your observations, what can you say determines the direction of movement of the loop when electricity passes through it?

Did the loop move towards or away from you in the second part of your experiment? With that in mind, now turn your cell the other way round. Complete the circuit as before. Which way does the loop move this time? Use the other pole of the magnet. Complete the circuit. Which way does the loop move? What also affects the direction of movement of the loop?

☆☆☆ A loop placed near a magnet moves when electricity passes through it. This is due to the reaction between the two magnetic fields. The direction of movement of the loop depends upon the pole of the magnet near it and also the direction of the current in the circuit.

What you have just observed is sometimes referred to as the CATAPULT EFFECT. The magnetic field of the magnet reacts with that of the loop (when electricity passes through it) and this results in the movement of the loop. The magnetic field of the magnet CATAPULTS (shoots) the moveable loop in a direction determined by the direction of the current and the pole of the magnet near the loop.

The 'catapult' effect of a magnetic field has a number of uses in everyday life. Its main use is in the electric motor - a device which converts electrical energy to kinetic energy.

THE ELECTRIC MOTOR

Electric motors form the heart of a whole range of electrical devices. Electric motors are used to start the engine of a motorcar, bus or tractor, move the windscreen wipers of a car, move electric locomotives, raise a lift in tall buildings, etc.

The electric motor uses 'catapult' field to produce motion (movement) and in the simple motor its important parts are a rotating coil and a magnet/magnets. Our copper loop has now been replaced by a coil and instead of using one magnet we will use two magnets with unlike poles facing each other to make the magnetic field stronger.

In Unit B you used a motor. You might have asked your teacher to explain how it worked. If he did explain I am sure you did not understand. I am sure you will now be able to understand. I would like you now to make a model of an electric motor of your own.

ACTIVITY 1 : MAKING A MODEL OF AN ELECTRIC MOTOR

You will need:

Your electric motor kit from the teacher
battery box (use a cell or two)

OR

steel strip with a hook.

50/60 cm of copper wire

split pins (2)

pop rivets (2)

leads (2)

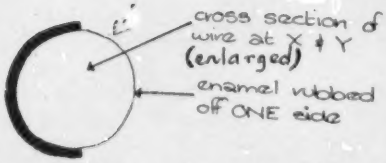
magnets (2)

circuit board

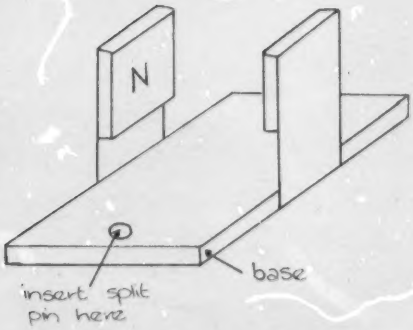
Open your kit and pick out the following items:
coil, split pins, connector leads, steel strip, magnets, plastic base, emery paper (or razor blade).

If you do not have a coil ready-made, you can quickly make one as follows: first wind a coil of about six turns made from 50/60cm of enamelled copper wire over two fingers, or three if yours are small! The ends should be twisted round once or twice and pulled straight as in the coil diagram below. Then proceed as in the instructions that follow.

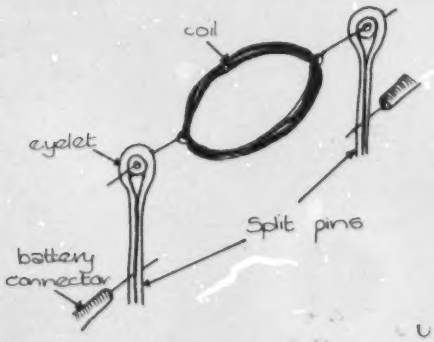
Pick up the coil which is made of copper wire with an insulating cover made of a special paint or enamel. Straighten the free ends, X and Y, of the coil. Hold the straight ends in your fingers and rotate the coil. It should rotate (spin) smoothly.



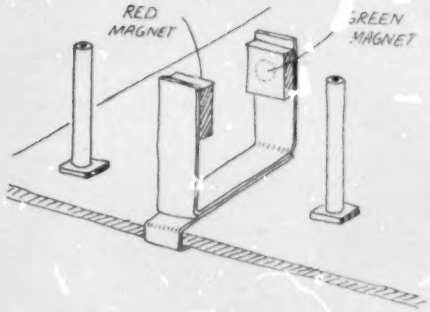
Remove enamel from one side only of the straight wires of the coil by rubbing with emery paper or scraping with a razor blade.



Place the plastic base between the steel strip and position your magnets as shown with the red and green spots facing.

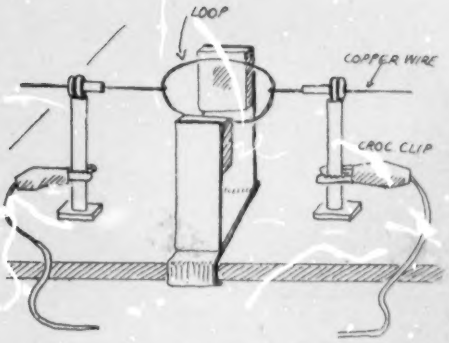


Insert the bare ends of connectors in the slits of the split pin.



OR

Fix the steel strip between two pillars of the circuit board and position your magnets as shown with unlike poles (green and red) facing.



Fix the leads to the pillars by means of crocodile jaws.
Then fit in the ends of the coil through the eyelets of the split pins to ensure a good smooth contact.

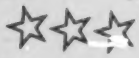
Mount the coil to the plastic base or pillars by inserting the pins in the holes of the base or circuit board pin. Rotate the coil to see if it does not touch the magnets. If it does then squeeze the sides of the coil in slightly. Your model is now ready for the test.

Connect the leads to a cell. To get the motor to start, give the coil a spin. Does the coil keep on rotating on its own? For best results the position of the magnets may need to be adjusted. If the motor (coil) does not work then check to see that the contacts are clean. Rub them with emery paper if necessary. What will happen if you use two cells instead of one? Note that it is important to disconnect your battery immediately after use, otherwise it may run down (become flat) quickly.

Before reading on, try to work out why the motor continues to turn when the battery is connected.

EXPLANATION:

If electricity from the cell flows first through X then through the coil and out through Y, in which direction does electricity flow through the top part of the coil? In which direction does electricity flow through the lower part of the coil?

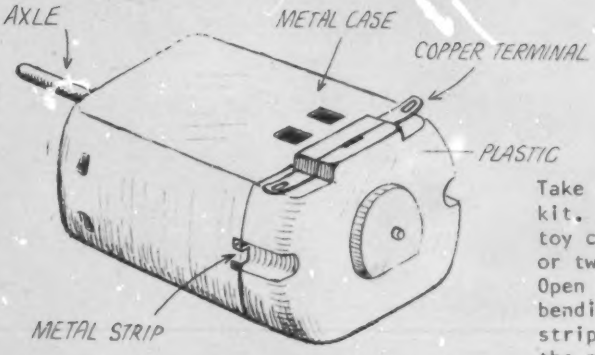


Electricity flows to the RIGHT in the top part of the coil and to the LEFT in the lower part of the coil. Because the coil is in the magnetic field of the two magnets this will make the top part move in one direction and the lower part in the opposite direction. (Remember the catapult effect of a magnetic field!). In this way the coil finds itself spinning (rotating). But will it continue to rotate if current continues to flow? Discuss this with your teacher.

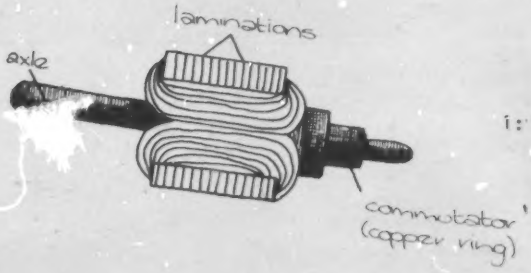
Do Exercise 4 Write a careful account of why the motor turns.

Let us now look at the factory-made electric motor.

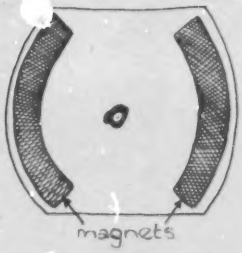
ACTIVITY ?: LOOKING AT A FACTORY-MADE MOTOR



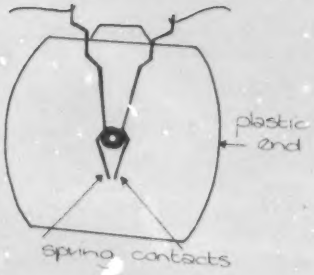
Take the electric motor from the kit. This is the type used in toy cars. Connect it to a cell or two. Does the motor work? Open the end of the motor by bending up the two small metal strips of the metal case holding the plastic part of the motor.



i: Pull out the rotating ARMATURE from the metal case. How many coils make up the armature?



2: Look inside the case and note the curved magnets.



3: Look inside the plastic end. Do you see the contacts? Find out how the current from the cell reaches the coil.

Please note the following characteristics of the factory-made motor:

1: There are three separate coils not one like in your model. This increases the power of the motor and makes the armature rotate more smoothly.

2: There are iron pieces (laminations) around which the coils are wound. This strengthens the magnetic field.

3: The magnets are curved to ensure that the magnetic field remains strong and uniform (same throughout) as the coil turns.

4: There are 3 gaps in the copper ring on which a pair of spring contacts are pressing. This commuter (copper ring) reverses the current 3 times when the coil turns once and this makes the coil continue turning smoothly in the same direction.

Lastly assemble the parts of the motor and bend down the metal strips of the case. Test the motor to see if it still works by connecting it to a cell.

Complete Exercise 4

A moveable conductor placed in a magnetic field moves when electricity passes through it. The direction of movement depends upon the direction in which the current flows and the direction of the magnetic field. This movement is the basis on which the electric motor works.

ELECTRIC GENERATOR

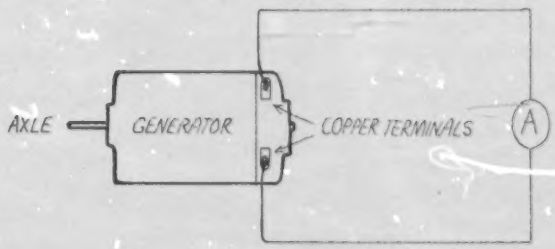
The electric motor you have just seen is, as you have seen earlier in Unit B, an energy converter. What energy changes take place in the motor? Discuss with teacher.

Let us now look at another energy converter - the electric generator. To generate means to PRODUCE. An electric generator produces electricity.

ACTIVITY 3: PRODUCING ELECTRICITY FROM A GENERATOR

You will need:

factory-made motor
ammeter-voltmeter and leads



Hold the motor in one hand.
Connect the motor to the ammeter.
What is the ammeter reading?
Now spin the axle of the motor a few times one way.
What do you notice on the ammeter?
What flows through the leads as you turn the axle?
Reverse the direction of spin.
Which way does the pointer move?

Remove the leads from the ammeter. Use these to connect the motor to the voltmeter. Spin the axle.
What happens to the pointer?

When a coil moves in a magnetic field electricity is generated (produced). A device which generates electricity in this way is called a GENERATOR. In our investigations the coil is rotated by hand or by a falling stone, as in Unit B and this generates electricity. The direction of the current produced depends upon the direction of rotation of the coil. The coil is called the ARMATURE.

Thus a motor converts electrical energy to mechanical energy and a generator called a DYNAMO, converts mechanical energy to electrical energy.

The discovery by Oersted in 1819 that an electric current produced a magnetic field was one of the connections scientists had sought between electricity and magnetism. The reverse process of producing an electric current from a magnetic field was also given considerable attention but it was Michael Faraday who, in 1831, first publicly announced the discovery of ELECTROMAGNETIC INDUCTION which means the production of electricity by a magnetic field. It was this effect which led to the construction of GENERATORS or DYNAMOS for the large-scale generation of electrical energy in power stations such as Kariba.

Now go back to Unit B and read about the generation of electricity at Kariba. Do you think you now know how an electric motor and a generator work? If you are in doubt seek help from your teacher.

Do Exercise 5 which your teacher has put on the board.

Electricity is produced by a generator by electromagnetic induction when a conductor moves in a magnetic field.

DIFFERENCE BETWEEN DIRECT CURRENT (DC) AND ALTERNATING CURRENT (AC)

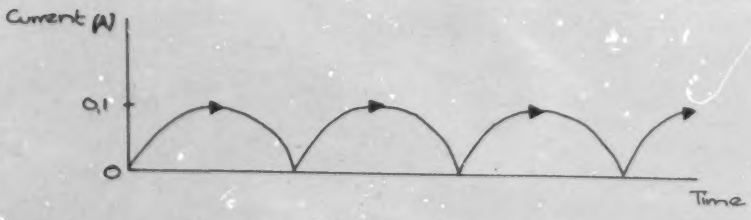
A torch cell or battery (rechargeable) produces a direct current (DC). This means that the current moves in one direction only.

ACTIVITY 4: GENERATING A DIRECT CURRENT

You will need:

your generator (electric motor)
ammeter and leads.

Connect the generator to an ammeter as before. The current is zerobefore you start rotating the axle. When you rotate the axle, a current is produced.
The ammeter reading rises to a certain number and then drops to 0 when you stop. This rise and fall is repeated as you rotate and stop.
The pattern (graph) to this rise and fall of the current is like this:

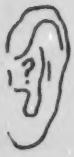


Turn the axle much faster than before.
Does the pointer get to 0? If you could turn the axle at a fast and constant speed will the pointer move up and down?
When this happens the graph will be like this:

Notice that the pointer will remain steady at, say, 0,1A mark.
When the rotation is reversed the current flows in the opposite direction. It is still D.C.

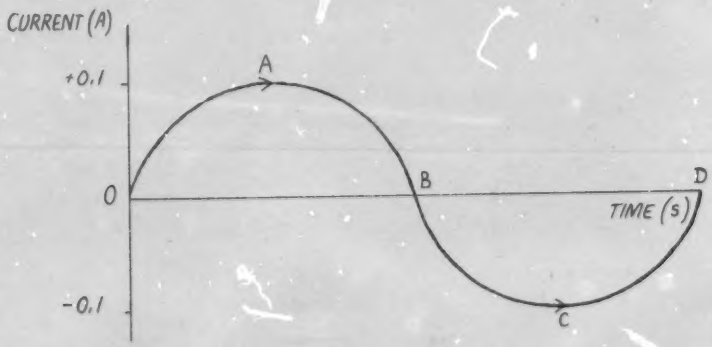
Alternating Current (A.C.)

The electricity produced at Kariba is produced in a different way from that we have just produced from a D.C. generator.
The generator at Kariba produces ALTERNATING CURRENT (A.C.).

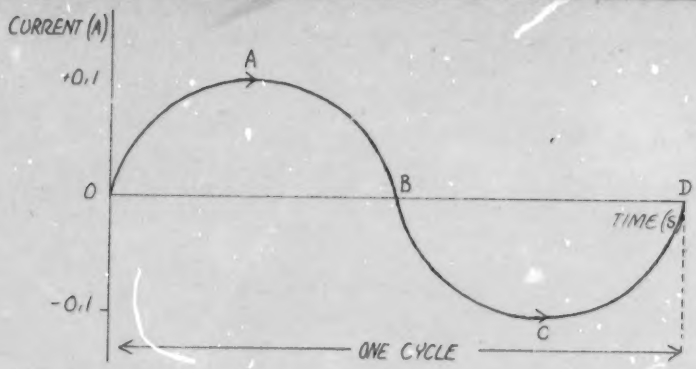


Similarly a bicycle generator produces alternating current (A.C.). Let us move to the teacher's desk for this demonstration experiment. Note carefully the movement of the pointer as the generator rotates slowly and quite fast. Then discuss your observations with your teacher.

Alternating current travels to and fro at regular intervals.
The graph below shows the movement.



The graph shows that the current moves in one direction during the first half (OAB) of the time and during the second half (BCD) it moves in the opposite direction.



One movement in one direction (CAB) and another movement in the opposite direction (BCD) make a CYCLE.

The electricity produced at Kariba travels to and fro 50 cycles in one second. It travels very fast indeed. It is this to and fro movement which produces a humming sound at the substation or in the electricity power lines.

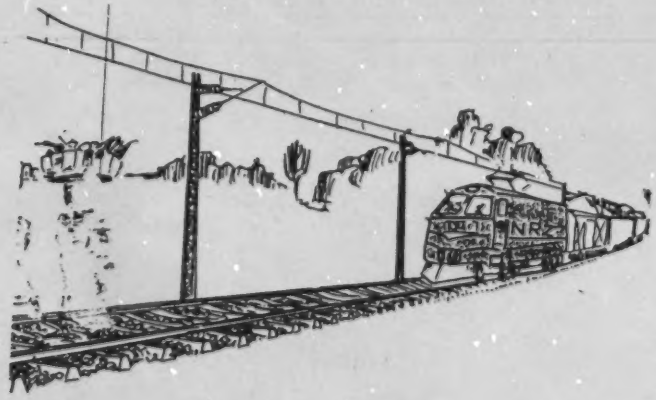
Alternating current is the electric current that reverses its direction at regular intervals.
What type of voltage (p.d.) drives a direct current and an alternating current? Discuss this with your teacher.

The difference between D.C. and A.C. is that direct current flows in one direction only whereas alternating current reverses its direction at regular intervals.

Answer Exercise 6 which your teacher has put on the board.

ELECTRIC TRAINS RUN BY ELECTRIC MOTORS

Electrification of the National Railways of Zimbabwe has just begun. With the passage of time the main centres - Bulawayo, Gweru, Harare and Mutare - will be served by electric trains.



Look at the diagram above. Do you see an electric engine connected to the electric cables? Good!
The engine runs on electrical energy instead of diesel/coal.
How does it work?

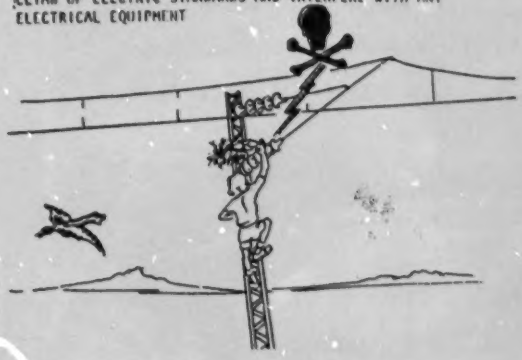
Our model of the electric motor converted electrical energy into Kinetic (movement) energy. Similaraly in the electric engine are big electric motors which convert electrical energy into kinetic energy. These motors are connected to the wheels of the engine. When the motors run they cause the engine and railway stock (wagons and coaches) to move as well.

The reason why our Railways are being electrified is to provide us with the most reliable, economic (cheap), safe and comfortable transport and travel services. Our transport and travel services will be cheap because we will not import large quantities of expensive diesel from abroad. Kariba supplies our Railways with the required electrical energy.

To move a long train, large amounts of electrical energy are needed to work the big electric motors. This means that the cables connected to the electric trains deliver LARGE CURRENTS at HIGH VOLTAGES and these spell out DANGER. There is no danger when you are inside travelling by train but your LIFE is in GREAT DANGER if you:

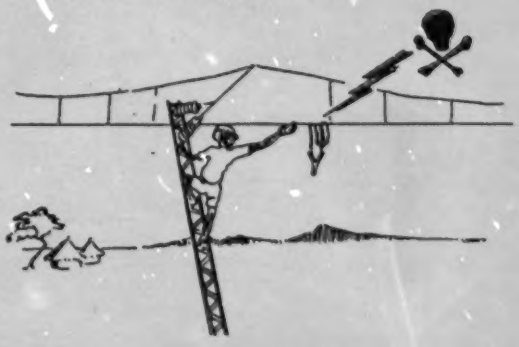
PLAY ANYWHERE NEAR THE ELECTRIFIED AREAS

CLIMB UP ELECTRIC STANDARDS AND INTERFERE WITH ANY ELECTRICAL EQUIPMENT

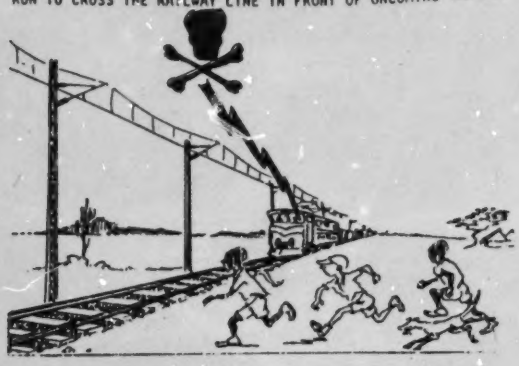


TOUCH BROKEN OVERHEAD LINES

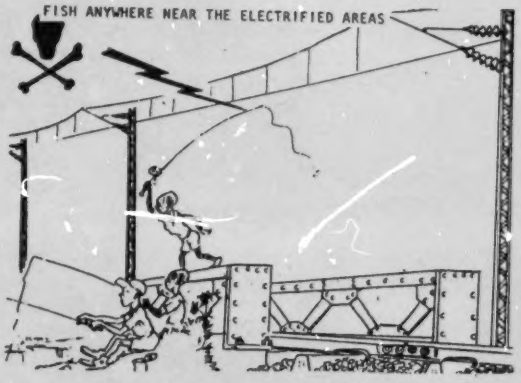
PULL ARTICLES OFF THE OVERHEAD LINES



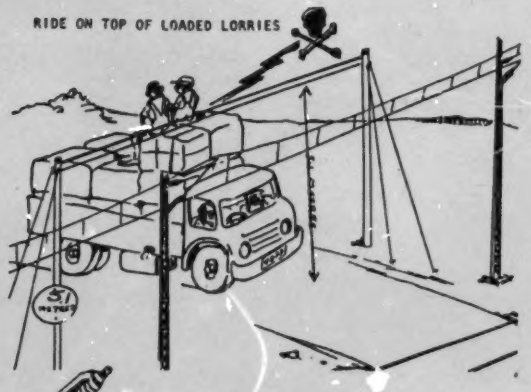
RUN TO CROSS THE RAILWAY LINE IN FRONT OF ONCOMING TRAINS.



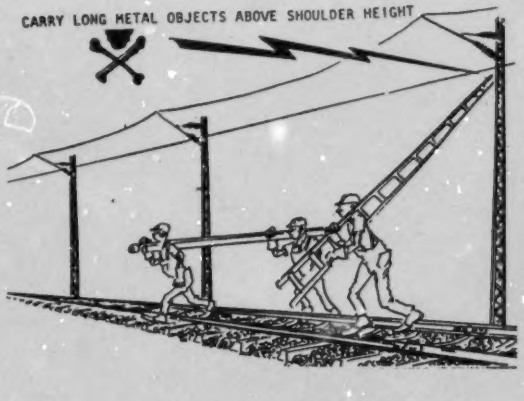
FISH ANYWHERE NEAR THE ELECTRIFIED AREAS



RIDE ON TOP OF LOADED LORRIES



CARRY LONG METAL OBJECTS ABOVE SHOULDER HEIGHT



Now answer Exercise 7

Now revise Part 1 of this Unit and answer 'How Much Do You Know?'

HOW MUCH DO YOU KNOW?

1. Work is the amount of .... and its units are ..... or .....
2. A joule is a unit of both ..... and .....
3. Power is .... in a given ..... or work done in a ....
4. To calculate electrical power we multiply ..... by ..... and the unit is ..... which is equal to .....
5. The power rating and the .....are usually marked on the appliance.
6. An electric bulb is marked 12V 24W.
   What current should flow through it?

7. Power appliances (stoves, kettle) use ..... effect of current. The ..... in these appliances convert electrical energy into ..... energy

Electric bulbs contain ..... which convert electrical energy into ..... energy and ..... energy.

8. A permanent magnet has two poles, a ..... pole at one end or side and a ..... pole at the other end or side. Like poles of magnets ..... and unlike poles ..... each other.

9. A nail placed in a coil through which electricity flows ..... the iron filings. When the circuit is broken the iron filings ..... showing that the ..... in the nail has been lost. This type of magnet is called an .....

10. When iron filings are sprinkled between two magnets they form a pattern. This pattern is called a .... which consists of lines of ..... These lines connect ..... poles.

11. A moveable conductor placed in a magnetic field will ..... in one ..... when a current passes through it and in the other direction when the ..... is .....

12. A motor converts ..... energy into ..... energy when it moves.

13. A dynamo or generator converts ..... energy into .... energy when the coil moves.

14. Direct current (D.C.) flows in .... only whereas alternating current (A.C.) ..... its ..... at regular intervals.

15. Electricity generated at Kariba travels to and fro ..... times per .....

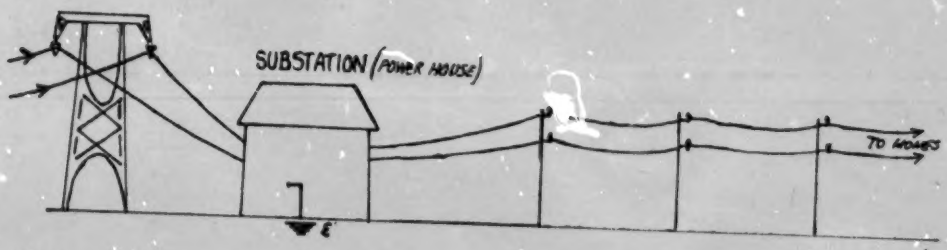
16. You should not play anywhere near the electrified areas (railway lines) because high ..... and ..... are dangerous.

PART 2

HOUSEHOLD ELECTRICITY

Electricity used in the home is at a much higher voltage (230V) than that of an ordinary cell (1,5v, 3.0v). It is therefore capable of giving you a SEVERE SHOCK or even KILL you should you touch any UNINSULATED conductor connected to the 'MAINS'. The mains are thick wire cables which supply electricity to the house. These high voltages are capable of driving a current through you and when this happens you get a shock or are killed (electrocuted). This is the reason why there are DANGER signs on electrical installations.

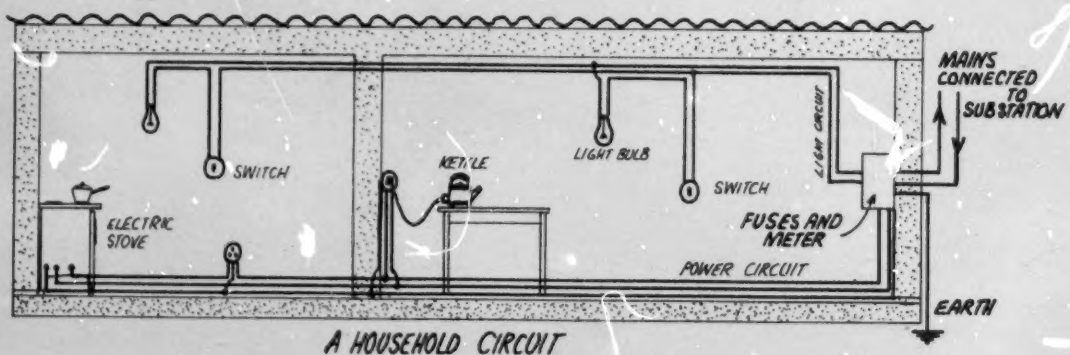
HOW ELECTRICITY GETS TO HOMES



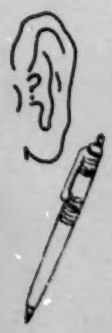
The electrical energy used in houses is supplied by wires (two) from the SUBSTATION or POWER HOUSE. These wires are called the 'MAINS'. The power house is also connected to Kariba by transmission lines.
(Also see the wall chart: ELECTRICITY FROM WATER.)

One of these two wires is called the "LIVE" and the other one is the "NEUTRAL" or "RETURN" wire.

The Neutral is connected to Earth (E) at the substation so that its POTENTIAL is ZERO (0V). The 'live' is at FULL POTENTIAL (230V).



A HOUSEHOLD CIRCUIT



The 'mains' enters the house at a convenient point and is joined to the FUSE BOX and METER. The fuse box contains fuses.
What is the use of the fuse box?
Discuss this with your teacher.

From the fuse box and meter the 'mains' branches into POWER CIRCUIT (for cooking, ironing etc.) and LIGHTING CIRCUIT.

Do Exercise 8 on Household Electricity.

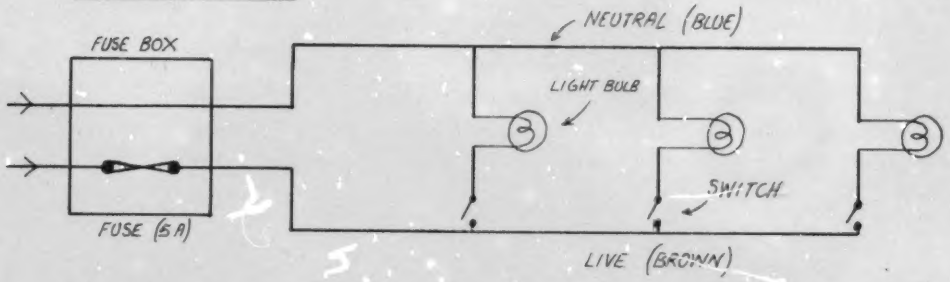
HOW A FUSE PROTECTS AGAINST FIRE BREAKING OUT IN A HOUSE WIRING SYSTEM

Fuses of suitable capacity are connected between the incoming electric power lines (in the fuse box) and the electric wires leading away to lighting and power circuits. If an electric circuit is OVERLOADED by operating a number of electrical appliances (a cooker, heater, iron) from it or if the bare (uninsulated) cables accidentally touch one another (short-circuit), then the EXTRA current will be drawn from the mains. The extra current heats the fuse wire causing it to become very hot and melt. As soon as the fuse wire melts (blows) the current is cut off. The melting of the fuse wire protects against fire breaking out in a house circuit.

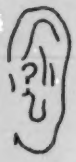
A CLOSER LOOK AT HOUSEHOLD CIRCUITS

On Page30you saw the diagram of a household circuit. The circuit divides into lighting circuit and power circuit. Let us look at each circuit in more detail.

LIGHTING CIRCUIT

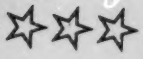


The lighting circuit consists of two wires, the live and the neutral which, from the fuse box, go right round the house. In each room a light bulb is fitted. Each bulb has its own independent circuit and is controlled by a switch.



How are light bulbs in this circuit connected?
To which wire (live or neutral) is a switch and a fuse fitted?

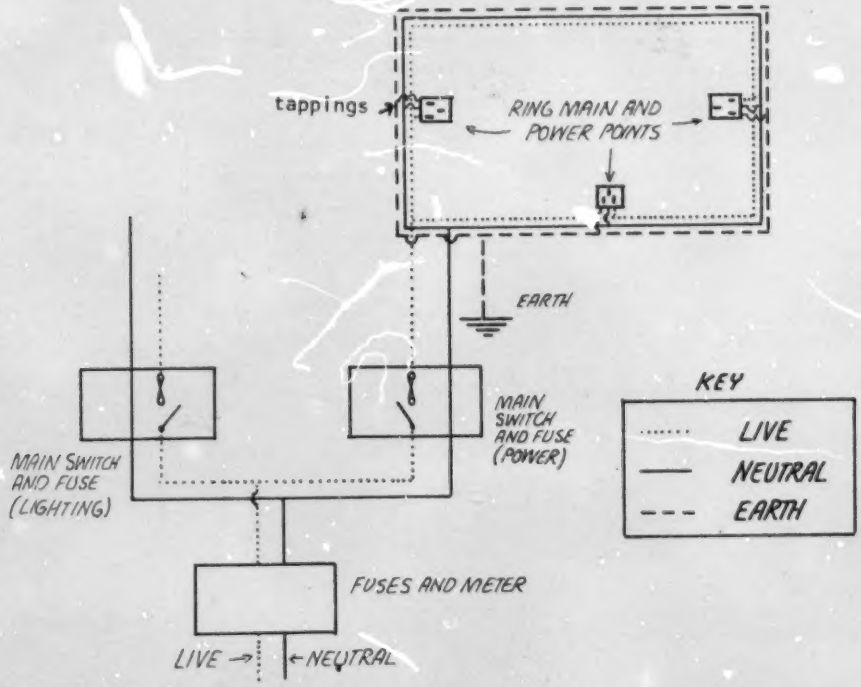
What will happen suppose the switches in the above diagram were fitted to the neutral instead of the live?
Discuss this with your teacher.



Bulbs are connected in parallel in a lighting circuit.
The fuse and the switches are connected to the LIVE wire <u>always</u>.

POWER CIRCUIT

The modern method of wiring power points is to use a ring-main.



The wiring from the meter passes to a main switch and fuse in the live wire. It then makes a complete circuit of the house eventually arriving back again at the main switch (power). The outlet sockets which are all of one size, are connected to tappings from the ring-main. The protective fuses are carried inside the plugs which are used to connect the various appliances to the sockets. The rating of the fuse can then be made to suit the particular appliances.

N.B. (A plug connected to a light bulb or television should have a 2A fuse whilst an electric heater needs a '13A' fuse).
Note also that the neutral wire makes a complete circuit of the house just like the live wire.

Ring-main is used to wire power circuits in houses.
Ring circuits usually have fused plugs which are used to connect the appliances to the circuit. Switches (not shown in the diagram above) are connected to the live wire so that the appliance is not "live" when the circuit is switched off.

The circuit is not affected should a fuse of one appliance blow. It is only the appliance's circuit which is cut off.

Do Exercise 9 .

HOW DO WE WIRE A PLUG?

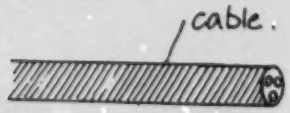
A cable from an appliance is connected to the ring-main by means of a PLUG. I would like you to connect the plug to this cable.

ACTIVITY 5 : CONNECTING A PLUG TO A POWER CABLE

For this activity you will need:

a length of power cable
a plug
a screw driver
a razor blade.

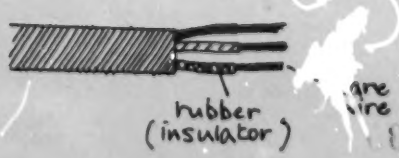
A THE CABLE



Pick the cable up. Do you see how thick it is?
Why do you think it is this thick?
Why is rubber or plastic used?
Look at the cable from one end.
How many conductors/leads are inside the cable?

Rubber or plastic is used in cables because it is an insulator. It protects the user against shock and prevents short circuits.

Using a razor blade carefully remove 3 or 4 cm of the outside rubber or plastic only . Do not remove the insulator around each conductor (lea Note the colours of the three insulated leads?



Remove ½cm of the insulation from the ends of the leads.

The wire leads are covered with insulators which have different colours. This is so that each lead can be identified. You may notice two different codes are used:

NEW COLOUR CODE	CONDUCTOR	OLD COLOUR CODE
BROWN	LIVE (L)	RED
BLUE	NEUTRAL (N)	BLACK
GREEN & YELLOW	EARTH (E)	GREEN

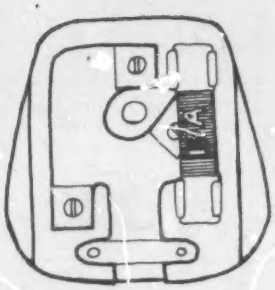
NOTE: The leads of your circuit board use the old code for live and neutral.

(You may be interested to learn that the new colour code was introduced because people who are colour blind cannot tell the difference between red and green.)

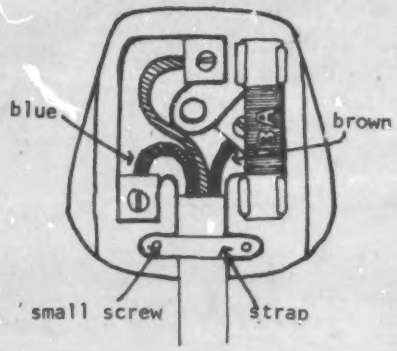
B THE PLUG

large screw

Pick up the plug. Look at it. How many flat pins has it got? What letters are marked against each pin? Compare the letters with the conductor column above.



Open the plug by unscrewing the big screw. Remove the top. Can you see the fuse? What is its rating? To which pin is the fuse connected?



Unscrew one of the small screws so that you can place the cable under the strap as in the diagram. Screw on to make the strap hold the cable firmly. Unscrew the small screws fitted to the flat pins. Twist the bare ends of the three leads. Push the bare end of the brown lead through the hole of the metal to which the fuse is fitted. Screw on to make a firm hold. Fix the bare end of the blue lead to the neutral pin. Finally fix the green/yellow lead to the Earth pin. Check that you have connected the correct coloured wire to each pin and that there are no stray loose ends or long bare lengths of wire which might cause a short circuit! Put on the cover and screw it on.

Now you have wired a power plug. If the cable were connected to a cooker and you had electricity you should be able to cook yourself some lunch!

When wiring a plug: the brown lead should be connected to the LIVE (L) pin, the blue lead to the NEUTRAL (N) pin and the green/yellow lead to the EARTH pin.

Remove the cable from the plug and return these to the teacher for storage.

Copy down in your books the colour code charts, and the diagram of a wired up plug.

HOW DO WE CHOOSE THE CORRECT FUSE FOR A PARTICULAR APPLIANCE?

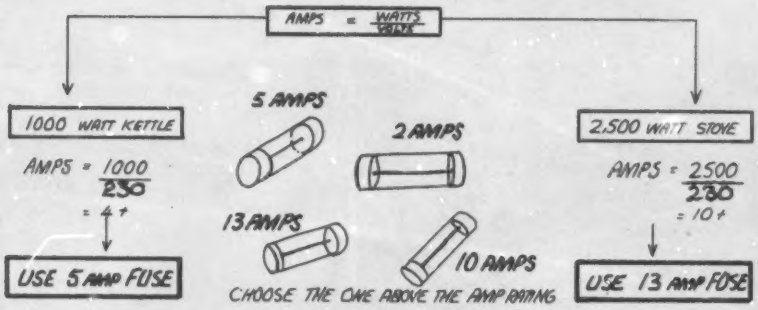
Earlier in the Unit we learnt that electrical power (in Watts) is related to current and potential difference (p.d.) in the equation:

WATTS = VOLTS x AMPERES

From this equation we can express current in terms of Watts and Volts:

$$\therefore \text{Amperes} = \frac{\text{Watts}}{\text{Volts}}$$

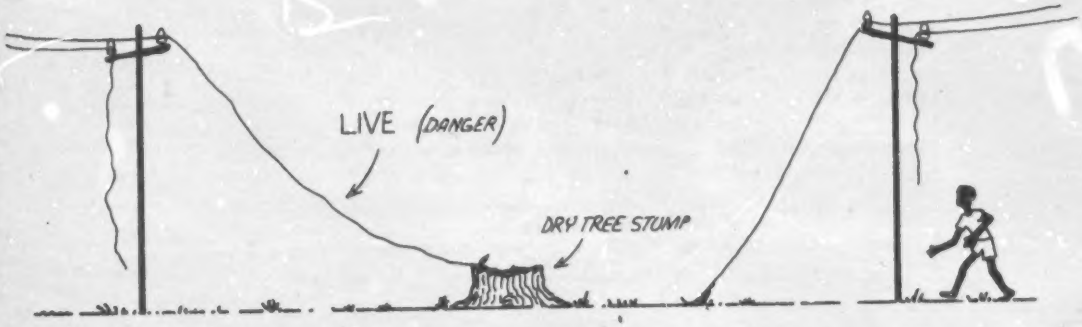
Since power and p.d. are usually marked on the appliance we can use the equation above to get the correct fuse for a particular appliance. The following diagram illustrates the method.



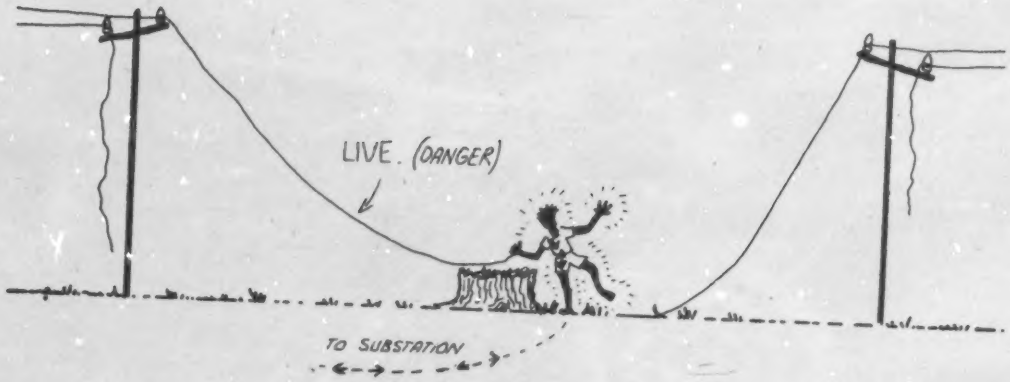
Do Exercise 10 which your teacher has put on the board.

WHAT ON EARTH IS THE EARTH WIRE FOR?

Earlier we said that the electricity which comes into homes comes from the substation which in turn, is connected to the generator at Kariba. We said that the Neutral is connected to Earth and has a zero potential. The live, on the other hand, is at full potential. For electricity to flow it needs a complete circuit. So, normally electricity flows into the house through the Live wire and back through the Neutral. Suppose the power line is broken by a falling dry tree near your house.



The live wire falls and rests on a dry stump (BAD CONDUCTOR). You run there to investigate. Overhead power lines have no colour code. The wires are bare.



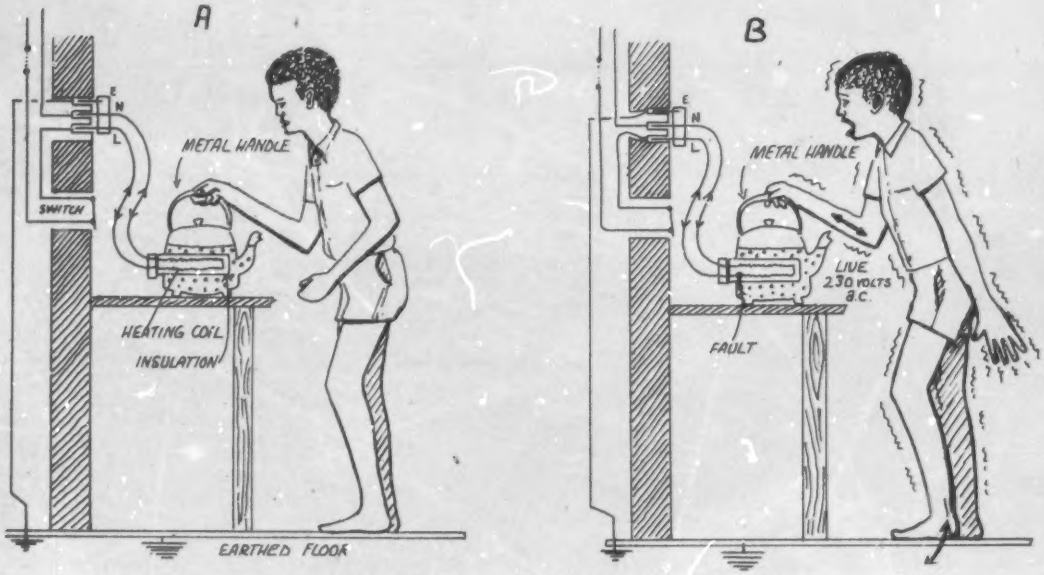
When you get there you decide to connect them. Unfortunately you pick the live wire. Immediately you touch the live wire you find yourself in GREAT PAIN and CRYING LOUDLY. You feel something passing through you. If you do not get help soon you would be dead in a very short time. (The one who comes to your help should separate you from the wire using a LONG DRY POLE. Should he/she try to pull you by the hand he/she will experience what you are also experiencing!) What you experience is a shock and should you die as a result of this we say you have been ELECTROCUTED. What makes you experience the shock?

Look at the diagram again. You should see arrow-heads on your body pointing down. High voltages are capable of forcing a small current through you and into the ground where it flows back to the sub-station. You have become a conductor, like a resistor, which completes the circuit. When the current flows through you some of the energy it carries is released in your body causing severe damage. We do not want this to happen to you.

So never touch overhead wires - either near your house or near the railway.

HOW EARTHING PROTECTS YOU

The ring-main diagram on Page 32 has an Earth (E) ring. Each power point is connected to the Earth ring which is connected to a cold water supply pipe or to a metal pipe in the ground. Let us look at the following diagrams.

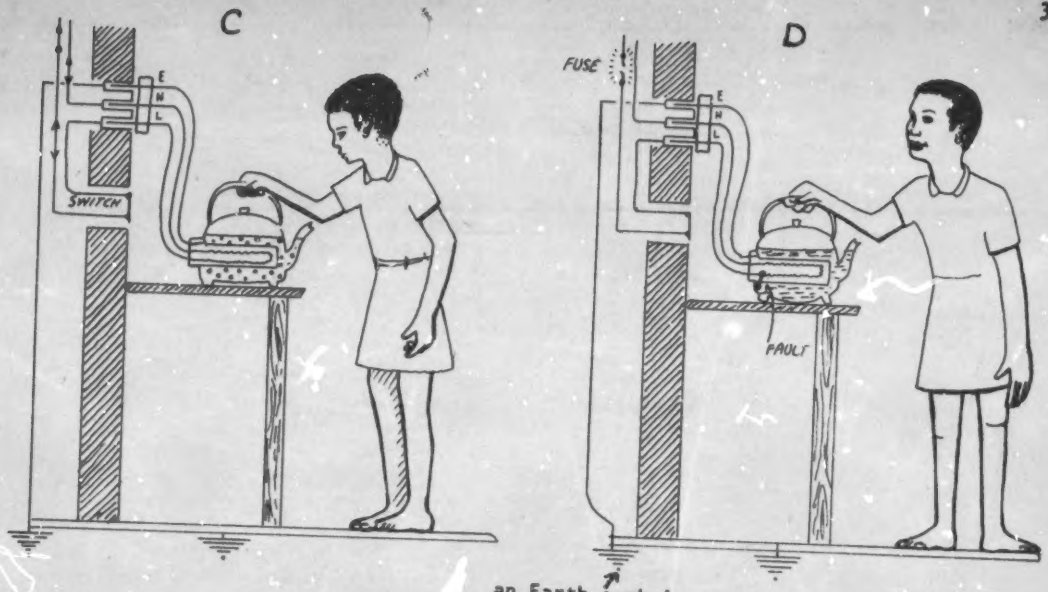


In diagrams A and B the electric kettle is connected to the power point (socket) in the wall by a lead (cable) with two conductors; a Live (L) and a Neutral (N) connected through the plug. The Earth wire is missing! This kettle is NOT earthed i.e. the metal casing of the kettle is not connected to the earthwire.

In diagram A it is safe to use the kettle to boil the water so long as the kettle is in good condition. In diagram B there is a fault. The heating element (coil) has broken loose inside the insulation, and its end nearest to the live side of the plug is making electrical contact with the metal case of the kettle. The kettle may still heat up normally, but the case is now connected to the full voltage of the mains. This means that the metal case is now 'live' i.e. electrical energy can flow from it. If the user touches it while the switch is 'on', the mains voltage (230V) will appear across his body, between his hand and his feet and this results in him receiving a SEVERE SHOCK. Thus this connection offers you no protection in the event of a fault in the appliance. This is similar to the diagram on Page 37

☆☆☆ FOR YOUR PROTECTION ALWAYS MAKE SURE ALL APPLIANCES CONNECTED TO THE POWER CIRCUIT ARE EARTHED.

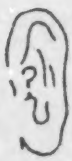
Let us now look at diagrams C and D over the page.



an Earth symbol

Diagram C and D a similar kettle is shown with all three pins correctly connected in the plug. The metal case of the kettle is connected to the earth wire (E). We say the body (metal case) of the kettle is earthed.

In diagram C the kettle is completely safe to boil water if it is in good condition. In diagram D, a fault similar to that in B has developed. The live end of the coil is now touching the metal case. But the metal case itself is connected to earth, so a very large current will begin flowing out of the live (L) wire through the fault and back to earth. This path offers very little resistance; the current therefore rises rapidly and almost instantly the fuse blows. Within a fraction of a second of the fault developing, the kettle is once again safe to handle and it will not be possible to heat water in the kettle until the fault has been repaired.



Notice that earthing and fusing work together. An earthing system could be an additional fire danger if there were no fuse in the circuit. This is because a large current passing through the earth wire, in the event of a short circuit, will make the wire so hot as to start a fire. (See Page of this Unit.)

Why are electric light bulbs not earthed?
Discuss this with your teacher.

Every power appliance should be earthed.
Earthing protects the user of an appliance against electrical shocks in the event of a fault in the appliance.
The symbol for the earth connection (E) is ⏚

Do Exercise 11

PAYING FOR THE ELECTRICAL POWER

In houses which use electricity there is a meter which informs the Power Company (Electricity Supply Commission - ESC for short) how much electrical energy the house has used over a period of time. This meter measures how many units of electrical energy have been used by electrical appliances in the house. Electricity is not free and people who use it receive a bill each month. The machinery at Kariba and the dam wall cost many millions of dollars and must be paid for. In the case of a coal furnace powerstation like the new one at Hwange the coal must also be paid for! This is why it is important to switch electrical appliances off when they are not in use.

Energy is measured in Joules and a WATT is energy being delivered or changed at 1 joule per second.

The Watt is too small to be used as a unit in measuring the quantity of energy used in houses. So a bigger unit is used and this unit is a Kilowatt. A kilowatt means 1 000 joules are delivered every second.

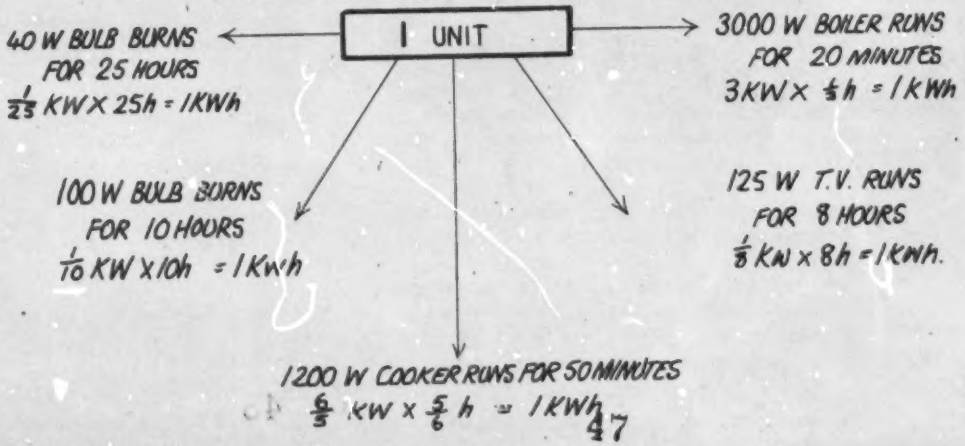
Quite often electrical engineers talk about a kilowatt-hour (kWh).
Can you work out what they mean?
Yes that is correct - a Kilowatt hour is an AMOUNT of energy.
It is often just called a UNIT of electricity.
It is equal to a power consumption of 1 000 Watts being used for 1 hour.
Can you work out how many joules in a kilowatt hour?
Discuss this with your teacher.

Of course an appliance which works at less power than 1 000W will take more than one hour to consume a kilowatt hour (Unit).
An appliance which works at a power greater than 1 000 Watts will consume a unit of electricity in less than one hour.
Think about these things very carefully.
Here are some examples to help you understand:

One unit of electrical energy is consumed by an electric heater whose power rating is 1 000 W (1 kW) if it is switched on for one hour (1 kW x 1h = 1 kWh).

One unit is used by an electrical iron whose rating is 500 W (0,5 kW) if it is left on for two hours ($\frac{1}{2}$ kW x 2 h = 1 kWh).

HOW LONG EACH APPLIANCE TAKES TO USE ONE UNIT


1 UNIT
40 W BULB BURNS FOR 25 HOURS
$\frac{1}{25}$ KW X 25h = 1KWh
3000 W BOILER RUNS FOR 20 MINUTES
3KW x $\frac{1}{3}$h = 1kWh
100 W BULB BURNS FOR 10 HOURS
$\frac{1}{10}$ KW x 10h = 1KWh
125 W T.V. RUNS FOR 8 HOURS
$\frac{1}{8}$ KW x 8h = 1KWh.
1200 W COOKER RUNS FOR 50 MINUTES
$\frac{6}{5}$ KW x $\frac{5}{6}$ h = 1KWh

Units used (in kWh) = Power of appliance (in kW) X Time of use (in hours)

∴ kWh = kW X h

The following example shows you how to use this formula:

A 100 W light bulb is switched on for 12 hours.
How many units of electrical energy are consumed?

$$100\ W = \frac{100}{1000}\ kW$$

$$= 0{,}1\ kW$$

$$\therefore \text{ Units used} = 0{,}1\ kW \times 12\ h$$

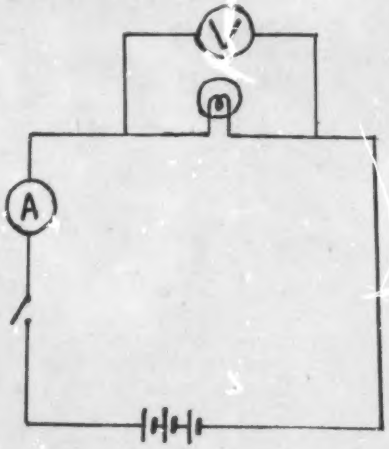
$$= 1{,}2\ kWh \text{ or } 1{,}2 \text{ units.}$$

Let us find out, on a smaller scale, the power of an electric bulb in the following experiment.

EXPERIMENT 5 : FINDING THE POWER OF A TORCH BULB

You will need:

3 new cells/fairly new in battery box
bulb holder and torch bulb
circuit board
leads
ammeter - voltmeter and leads
switch



Assemble the circuit as in the diagram above.
Complete the circuit and take the ammeter and the voltmeter readings. Break the circuit and then calculate the power (in watts) of the torch bulb as follows:

EXERCISE 12 : CALCULATING THE POWER OF A TORCH BULB

(1) p.d. across the bulb = V

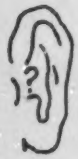
current in the circuit = A

∴ Power = volts x Amperes

= Watts.

Note that your answer should be corrected to the first decimal place.

(2) Express your answer in kW (divide by 1 000).



(3) How many units of energy will be consumed if the bulb is left glowing for 10 hours?

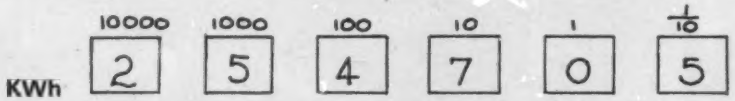
Are your answers the same in the whole class?
Discuss your results with the teacher.

In everyday life people have no time to calculate electrical power and the units of energy consumed as you have just done. Instead a meter is included in the mains to give them the readings of the energy consumed.

This is what we are going to do next.

READING ELECTRICAL ENERGY UNITS FROM A DIGITAL METER

On the face of the electricity meter are small boxes in which numbers appear as electrical energy is consumed.
This is what you might see:



The reading is 25 470,5 units.

How is your consumption of electrical energy per month calculated?

The meter reader has your last month's reading.
He/she then takes the meter reading on this visit.
Your energy consumption can now be found by subtraction.
Here is an example:

PREVIOUS READING (Last month)

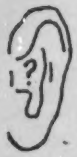
10000	1000	100	10	1	$\frac{1}{10}$
2	5	4	7	0	5

PRESENT READING

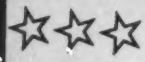
10000	1000	100	10	1	$\frac{1}{10}$
2	5	9	8	0	5

Number of units consumed = 25980,5 − 25470,5 kWh

= 510 kWh



Your teacher is going to show you how to read another kind of meter called DIAL METER. Listen carefully and then practise reading the meter with your friend.



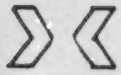
Units used = Present reading − Previous reading

COST OF ELECTRICAL ENERGY USED

To calculate the cost of energy used per month you need to know the number of units and the cost per unit. The average cost per unit in Zimbabwe is about 4 cents (1983).
What will your electricity bill be this month?

Cost of 510 units at 4c each = $\$ \frac{510 \times 4}{100}$

= $20,40



The unit of electrical energy is a kilowatt-hour (kWh).

kWh = kW x h

Units consumed = Present − Previous reading
Cost of energy used = units (kWh) x cost of a unit

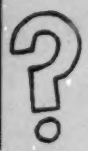
Do Exercise 13 which your teacher has put on the board.

CONCLUSION

Electricity is the most useful form of energy we have. It is useful because it can easily be moved from place to place along wires. It is also useful because it can conveniently and efficiently be converted to other forms of energy.

One day we hope wires will be connected to all villages throughout Zimbabwe so that all citizens can enjoy the services of this very efficient servant!

Revise Part 2 of this Unit and then answer 'How Much Do You Know?'



HOW MUCH DO YOU KNOW?

1. Household electricity is dangerous because it is at a .... which is capable of giving you a .... should you touch an ..... conductor connected to the .....
2. The mains consists of two wires, the ..... which is at full potential and the ..... which is connected to ..... at the substation and is at..... potential.
3. When the mains enter a house it is first joined to the ..... a safety device that cuts off the ..... if too high a ..... is passing into the house, and then to the ..... which records the consumption. From there the mains branches into the lighting circuit and the ..... circuit.
4. A ..... which is included in the circuit prevents overheating of cables because it easily ..... and breaks the circuit should the ..... become too high.
5. Switches and fuses are always connected to the ..... wire.
6. The new colour code is BROWN for ....., BLUE for .....; and ..... for earth.
7. Earthing of the power circuit protects you against ..... in the event of a fault in the appliance.
8. The unit of electrical energy is a ..... which is the energy used by a ..... appliance operating for ....
9. Earthing is not usually considered necessary on lighting circuits because their ..... parts are not normally touched by hand.
10. The .... is a modern method of wiring power points.

SUMMARY

1. a) Mechanical work is the amount of energy transferred or changed.
   b) Work = Force (N) x Distance (m) moved by the force.
   c) Unit of work is a Nm = 1 Joule (J).

2. A Joule (J) is a unit of work as well as energy.

3. a) Electrical power is energy transfer per second or work done per second. It is the rate of doing work.
   b) Power = Amperes x Volts.
   c) A Watt (W) is a unit of power delivered or transferred when one joule of work is done in one second.
   d) 1W = 1 J/s = Ampere x Volt.

4. The power rating (in Watts) and p.d. are usually marked on electrical appliances.

5. Electrical energy can be converted into other forms such as light, heat, magnetic and chemical energy.

6. A piece of metal (steel), that attracts iron and steel objects is called a permanent magnet.

7. A magnet has two poles, a North and a South pole.

8. A magnetic field which consists of lines of force exists around a magnet.

9. Unlike poles attract and like poles repel.

10. A conductor e.g. a coil is an electromagnet only when electricity passes through it.

11. A conductor through which electricity flows will move in a definite direction when placed near a permanent magnet. The direction of movement of the conductor depends upon the direction of the electric current and also the pole of the magnet near it. The movement of the conductor is called the 'catapult' effect.

12. The 'catapult' effect is used in electric motors or dynamos.

13. The electric motor consists of a coil (armature) and a magnet or magnets.

14. The electric motor converts electrical energy into kinetic energy (mechanical energy).

15. A device used to convert mechanical energy into electrical energy is called a generator.

16. A generator produces electricity by electromagnetic induction when a conductor moves in a magnetic field.

17. Direct current (D.C.) is current which flows in one direction only. A torch cell produces D.C.

18. A bicycle dynamo (generator) produces alternating current (A.C.). Alternating current travels to and fro at regular intervals.

19. One movement in one direction followed by another movement in the opposite direction is called a cycle.

20. The generators at Kariba produce A.C. which travels to and fro 50 times per second. (50 cycles/second.)

21. Electric trains in Zimbabwe need high currents and high voltages. Therefore it is extremely dangerous to play near electrified railway lines.

22. Household electricity is dangerous because it is at a high voltage which is capable of giving you a severe shock should you touch an uninsulated conductor connected to the mains.

23. The mains consists of two wires, the live which is at full potential and the neutral which is connected to earth at the substation and is at zero potential.

24. When the mains enter a house it is first joined to the fuse box, a safety device that cuts off the electricity if too high a current is passing into the house, and then to the meter which records the consumption. From there the mains branches into lighting and power circuits.

25. A fuse which is included in the circuit prevents overheating of cables because it easily melts and breaks the circuit should the current become too high.

26. a) An electric appliance connected to a power cirucit is protected against damage by a cartridge fuse of suitable rating.
    b) The correct fuse rating is found by dividing the power (Watts) of the appliance by the volts (p.d.) and then choosing the fuse rating slightly greater than the answer obtained.

27. Switches and fuses are always connected to the live wire.

28. The new colour code is; BROWN for live; BLUE for neutral; and green/yellow for earth.

29. Earthing of the power circuit protects you against electric shock in the event of a fault in the appliance.

30. The unit of electrical energy is a kilowatt-hour which is the energy used by a 1 000-Watt appliance operating for one hour.

31. Earthing is not usually considered necessary on lighting circuits because their metal parts are not normally touched by hand.

32. The ring main is a modern method of wiring power points.